SURFACE ACOUSTIC WAVE FILTER WITH ATTENUATION POLES

BACKGROUND OF THE INVENTION

The present invention relates to a band-pass filter of

5   a ladder type configuration using a surface acoustic wave (SAW) resonator in small-sized mobile communication devices such as mobile telephones, particularly to a SAW filter with attenuation poles having high attenuation in an attenuation band and low insertion loss in a pass band.

10   In recent years, mobile communication device terminals such as small-sized, lightweight mobile telephones have been developed rapidly. In accordance with this, the realization of reduction in size and of high performance in components to be used is being conducted. In response to this, RF (radio

15   frequency band) components using a SAW filter are developed and used. Particularly, the SAW filter is developed actively to partly become commercially available because it is a device that greatly contributes to the realization of reduction in size of RF parts.

20   In order to enhance the performance of the mobile communication device terminals, a high-performance SAW filter is demanded which has lower insertion loss in a pass band and high attenuation in attenuation bands.

The high-performance SAW filter is used in components

25   for branching, inputting and outputting signals in the mobile

communication device terminals.

A traditional ladder type SAW filter forming the high-performance SAW filter is described in Band pass filter with low loss using SAW resonators, Sato, et al., IEICE Ronbunshi

5   A, vol. J76-A, No. 2, pp. 245-252 (1993).

In addition, an attenuation pole filter shown in Fig. 12 added with an attenuation pole inductance L (330) is used as a high-performance filter.

Fig. 12 is a circuit diagram illustrating that a two-port

10   circuit 1 (380) of a traditional ladder type SAW filter formed of three series arms S1 (310), S2 (311) and S3 (312) and two shunt arms P1 (320) and P2 (321) is serially connected to a two-port circuit 2 (381) provided with an attenuation pole inductance L (330).

15   As described in JP-A-10-163808, in the SAW filter with attenuation poles shown in Fig. 12, attenuation poles are formed in an attenuation band on the high frequency side of the pass band by the attenuation pole inductance L (330), in addition to the characteristics of the traditional ladder type SAW filter.

20   The attenuation poles can provide certain high attenuation characteristics in the attenuation characteristics on the high frequency side of the pass band.

SUMMARY OF THE INVENTION

25   In order to enhance the performance of the recent mobile

communication device terminals, a high-performance SAW filter is demanded which has lower insertion loss in a pass band and high attenuation in the attenuation band on the low frequency side of the pass band. The high performance SAW filter is being

5 investigated with the use of traditional bonding wire, but satisfying characteristics are not obtained yet under present circumstances.

In the traditional mobile communication device terminals such as mobile telephones, a SAW filter with attenuation poles

10 having certain high attenuation characteristics in the attenuation band on the high frequency side of a communication band is shown in Fig. 12.

On this account, the circuit shown in Fig. 12 is used when attenuation poles need to be formed in the attenuation

15 band on the high frequency side, and the traditional bonding wire is used for the attenuation pole inductance L (330) shown in Fig. 12.

In this example, the traditional bonding wire is used as the inductance L to vary the frequency of the attenuation

20 poles by this L value, and the characteristics are changed to realize certain high attenuation. However, satisfying characteristics cannot be obtained yet.

Furthermore, high attenuation characteristics are demanded to provide in the attenuation band on the low frequency

25 side, and attenuation poles need to be formed in the band.

However, the traditional bonding wire is also used in the case. As a SAW filter with attenuation poles responding to this, a film is used in which the attenuation pole frequency of the attenuation band on the low frequency side of the pass band

5 is adjusted by using the traditional bonding wire of the shunt arms in the ladder type SAW filter. However, required characteristics are not satisfied in this case as well.

In the mobile communication device terminals such as mobile telephones, a SAW filter with attenuation poles is desired

10 which has high attenuation characteristics in the attenuation bands on the low frequency side and the high frequency side of the pass band. As a SAW filter with attenuation poles responding to this, a SAW filter with attenuation poles is used in which the traditional bonding wire is used as the inductance,

15 an attenuation pole frequency is formed in the attenuation band on the low frequency side of the pass band, and the attenuation pole frequency is varied to provide high attenuation in the filter characteristics. However, the required characteristics are not satisfied.

20 In view of the problems, an object of the invention is to provide a high-performance SAW filter having lower insertion loss in a pass band and high attenuation in an attenuation band on the low frequency side of the pass band.

The invention adapts the following schemes for solving

25 the problems.

(1)   In a surface acoustic wave filter with attenuation poles

configured of a two-port circuit for filtering for forming a

ladder type surface acoustic wave filter with a surface acoustic

wave resonator; and a two-port circuit for impedance formed

5   of an impedance serially connected, the impedance of the two-port

circuit for impedance is configured so as to form an attenuation

band of a predetermined width having a sufficient attenuation

characteristic on a low frequency side of a pass band.

(2)   In the surface acoustic wave filter with attenuation poles

10   as in (1), the impedance of the two-port circuit for impedance

is formed of a resistance and an inductance.

(3)   In the surface acoustic wave filter with attenuation poles

as in (1), the impedance of the two-port circuit for impedance

is formed of an impedance of a bonding wire.

15   (4)   In a surface acoustic wave filter with attenuation poles

configured of a two-port circuit for filtering for forming a

ladder type surface acoustic wave filter with a surface acoustic

wave resonator; and a two-port circuit for impedance formed

of an impedance serially connected, the two-port circuit for

20   impedance is configured of a π type circuit formed of three

impedances so as to form an attenuation band of a predetermined

width having a sufficient attenuation characteristic on a low

frequency side of a pass band.

(5)   In the surface acoustic wave filter with attenuation poles

25   as in (4), a bonding wire is used as the three impedances of

the two-port circuit for impedance.

(6)　In the surface acoustic wave filter with attenuation poles as in (2), two bonding wires with three electrodes are used as the impedance of the two-port circuit for impedance.

5　(7)　In the surface acoustic wave filter with attenuation poles as in (2), two bonding wires with three electrodes are used for the impedance of the two-port circuit for impedance, and a capacitance is connected in parallel to one of the bonding wires.

10　(8)　In the surface acoustic wave filter with attenuation poles as in any one of (1) to (7), an inductance is set almost constant to 1 nH and a resistance is set to any given value ranging from 0.20 to 1.20 Ω in the impedance.

(9)　In the surface acoustic wave filter with attenuation poles as in any one of (1) to (7), an inductance is set almost constant to 0.5 nH and a resistance is set to any given value ranging from 0.10 to 0.60 Ω in the impedance.

BRIEF DESCRIPTION OF THE DRAWINGS

20　The teachings of the invention can be readily understood by considering the following detailed description in conjunction with the accompanying drawings, in which:

Fig. 1 is a diagram illustrating the circuit configuration of a first embodiment according to the invention;

25　Fig. 2 is a diagram illustrating a lumped constant

equivalent circuit of Fig. 1 for describing the first embodiment according to the invention;

Fig. 3 is a diagram illustrating a half circuit of the lumped constant equivalent circuit shown in Fig. 2 for describing the relationship between the characteristics and component devices of the first embodiment according to the invention;

Fig. 4 is a lattice type equivalent circuit of the first embodiment according to the invention;

Fig. 5 is a schematic diagram illustrating a second embodiment according to the invention;

Fig. 6 is a schematic diagram illustrating Example 1 of attenuation pole impedance according to the invention;

Fig. 7 is a diagram illustrating an equivalent circuit of Example 1 of attenuation pole impedance according to the invention;

Fig. 8 is a schematic diagram illustrating Example 2 of attenuation pole impedance according to the invention;

Fig. 9 is a diagram illustrating an equivalent circuit of Example 2 of attenuation pole impedance according to the invention;

Fig. 10 is a graph summarizing the characteristics of Tables 2 and 4 of the invention;

Fig. 11 is a diagram illustrating 'attenuation width' of the invention; and

Fig. 12 is a diagram illustrating a circuit configuration

in which the two-port circuit 1 (380) of a ladder type SAW filter

formed of three series arms S1 (310), S2 (311) and S3 (312)

and two shunt arms P1 (320) and P2 (321) is serially connected

to the two-port circuit 2 (381) provided with the attenuation

5   pole inductance L (330).

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the invention will be described in detail

based on the drawings.

10

First Embodiment

Fig. 1 is a diagram illustrating the circuit configuration

of a first embodiment according to the invention.

The first embodiment is configured in which a two-port

15   circuit for filtering 1 (180) formed of a ladder type SAW filter

of two-stage π type is serially connected to a two-port circuit

2 (181) using an attenuation pole impedance Z_{11} (140) serially

connecting a resistance R_{11} to an inductance X_{11}, as depicted

by solid lines in Fig. 1.

20   More specifically, a series arm S1 (110) is serially

connected between an input terminal IN (103) and an output

terminal OUT (104), shunt arm P1 (120) and P2 (121) are connected

in parallel to the both ends of the series arm S1 (110) for

forming the ladder type SAW filter of two-stage π type.

25   The two-port circuit for impedance 2 (181) is formed of

the attenuation pole impedance Z_{11} (140).   The impedance Z_{11} (140) is configured of $R_{11} + jX_{11}$.

The invention is characterized in that the two-port circuit for impedance 2 (181) is configured in which the pole
5   frequency of the attenuation band on the low frequency side can be varied by the real part R_{11} and the imaginary part X_{11} of the attenuation pole impedance Z_{11}.

Fig. 2 is a diagram illustrating a lumped constant equivalent circuit of Fig. 1 for describing the first embodiment
10   according to the invention.

Fig. 3 is a diagram illustrating a half circuit of the lumped constant equivalent circuit shown in Fig. 2 for describing the relationship between the characteristics and component devices of the first embodiment according to the invention.
15   The lumped constant equivalent circuit shown in Fig. 2 is configured in which a two-port circuit of a π type filter formed of a series arm S1 (410) having an impedance $2ZS_{11}$, and shunt arms P1 (420) and P2 (421), each having an impedance ZF_1, is serially connected to a two-port circuit formed of an impedance
20   Z_{11} (440) having $2R_{11} + j2X_{11}$.

In the half equivalent circuit shown in Fig. 3, a series arm ZS_{11} (510) is connected between an input terminal IN (560) and a terminal M2 (570), a shunt arm (520) having an impedance ZF_1 and an impedance (540) having $R_{11} + jX_{11}$ are serially connected
25   between the input terminal IN (560) and an input terminal E1

(561), and a node of the shunt arm ZF$_1$ (520) and the impedance Z$_{11}$ (540) is connected to a terminal M3 (572).

In Fig. 3, suppose an input impedance is Z$_1$ where the terminal M2 (570), the terminal M3 (572) and a terminal E2 (571) are opened, and an input impedance is Z$_2$ where the terminal M2 (570), the terminal M3 (572) and the terminal E2 (571) are short-circuited, Z$_1$ and Z$_2$ are given by Equation (1) and Equation (2), respectively.

$$Z_2 = ZF_1 + R_{11} + jX_{11} \tag{1}$$

$$Z_1 = ZF_1 * ZS_1/(ZF_1 + ZS_1) \tag{2}$$

Fig. 4 is a lattice type equivalent circuit of the first embodiment according to the invention.

The characteristics of the first embodiment can be evaluated by converting the circuit shown in Fig. 1 to the lattice type circuit shown in Fig. 4 in equivalent circuit with Z$_1$ and Z$_2$. F matrix (four-terminal matrix [F]) in this case can be given by Equation (3).

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \frac{1}{Z_2 - Z_1} \begin{pmatrix} Z_1 + Z_2 & 2Z_1Z_2 \\ 2 & Z_1 + Z_2 \end{pmatrix} \tag{3}$$

Accordingly, since a coefficient S of operating transmission is S = (A + B + C + D)/2 from Equation (3), it is evaluated by using Equation (4).

$$S = \frac{(Z_1 + Z_2) + Z_1Z_2 + 1}{Z_2 - Z_1} \tag{4}$$

An attenuation characteristic α (ω) is given by Equation

(5).

$$\alpha (\omega) = -20*LOG|(S)| \quad (dB) \qquad (5)$$

From Equations (4) and (5), the attenuation pole frequency of the attenuation characteristic $\alpha (\omega)$ is the following case.

In the case of the traditional ladder type SAW filter, it is known that attenuation poles are formed under the conditions that the impedances Z_2 and Z_1 are infinite and zero.

In addition to the conditions, the invention is characterized in that the attenuation pole frequency is formed also in the case where $Z_2 = Z_1$ and the attenuation pole impedance Z_{11} (140) has the real part and the imaginary part.

In the meantime, the traditional bonding wire only has an inductance and the frequency is formed in the imaginary part alone. More specifically, in the invention, the attenuation characteristic can be changed also in the real part.

Hereinafter, a SAW filter for Cdma-One will be exemplified to describe the usability of the invention.

Table 1 shows the configuration of resonators, the series arm and the shunt arms shown in Fig. 1.

Table 1

Configuration of resonators	Series arm S1 (110)	Shunt arm P1 (120)	Shunt arm P2 (121)
Intersection length (μm)	60	70	70
Logarithm	60	80	80

Table 2 shows the usability of the invention.

Table 2

1-1. Attenuation pole inductance L is 1 (nH)

19.0 dB Width	4	14	15.8	16.1	16.2	16.1	15.9	15.5	15
R (OHM)	4.00	2.00	1.20	0.80	0.60	0.40	0.20	0.12	0.0004
L (nH)	1	1	1	1	1	1	1	1	1
Q	1	2.5	5	7.5	10	15	20	50	1000

5   1-2. Attenuation pole inductance L is 0.5 (nH)

24.0 dB Width	3	8.5	9.2	9.2	9	8.9	8.8	8.5	8
R (OHM)	2.00	1.00	0.60	0.40	0.30	0.20	0.10	0.06	0.0002
L (nH)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Q	1	2.5	5	7.5	10	15	20	50	1000

Traditionally, as a scheme to obtain high attenuation characteristics, the response is that the bonding wire is used as the attenuation pole inductance L to form attenuation poles

10   in the attenuation band as described in the publicly known document.

More specifically, the traditional bonding wire in which the resistance value can be ignored and only the inductance acts as impedance is used to form attenuation poles in the

15   attenuation band.

In the meantime, as shown in Table 2, the invention can obtain the high attenuation characteristics in which at least a resistance component is increased in addition to the impedance of the traditional bonding wire and thus the attenuation pole

frequency and the attenuation characteristic can be varied without changing the pass band characteristics.

The bonding wire of the invention is a line that at least a resistance component is increased in addition to the impedance of the traditional bonding wire. The impedances are set to the relationship described below.

Hereinafter, the bonding wire of the invention will first be described based on Figs. 6 to 9.

Fig. 6 is a schematic diagram illustrating Example 1 of attenuation pole impedance according to the invention.

Fig. 7 is a diagram illustrating an equivalent circuit of Example 1 of attenuation pole impedance according to the invention.

Fig. 8 is a schematic diagram illustrating Example 2 of attenuation pole impedance according to the invention.

Fig. 9 is a diagram illustrating an equivalent circuit of Example 2 of attenuation pole impedance according to the invention.

Fig. 6 is an example of attenuation pole impedance using the bonding wire of the invention. The bonding wire of the invention is formed to be a connecting wire 102, and an electrode 1 on a piezoelectric substrate 100 side is connected to an electrode 2 on a package 101 side.

Fig. 7 depicts an equivalent circuit of Fig. 6, in which an electrode 112 (110) connected to the electrode 1 on the

piezoelectric substrate 100 side is connected to an electrode 113 (111) connected to the electrode 2 on a package 101 side by a series circuit formed of a resistance R_{11} and an inductance L_{11}. More specifically, it shows that the impedance of the

5 connecting wire 102 formed of the bonding wire of the invention is $R_{11} + j\omega L_{11}$.

Moreover, an example that the reactive component of impedance can be adjusted is shown in Fig. 8. The bonding wire of the invention is formed to be a connecting wire (1) 126 and

10 a connecting wire (2) 127 to connect an electrode (1) on a piezoelectric substrate 120 side, an electrode (2) on a package 121 side and an electrode (3) on a package 122 side to each other. Furthermore, a capacitance substrate 123 for adjusting the reactive component is connected between the electrode (2)

15 on the package 121 side and the electrode (3) on the package 122 side through normal connecting wires (C1) 124 and (C2) 125 which can ignore resistance values and are unrelated to the bonding wire of the invention.

Fig. 9 depicts an equivalent circuit of Fig. 8, in which

20 an electrode 133 (130) connected to the electrode 1 on the piezoelectric substrate 120 side is connected to an electrode 134 (131) connected to the electrode 2 on the package 121 side by a series circuit formed of a resistance R_{11} and an inductance L_{11}. An equivalent circuit is formed in which the electrode

25 134 (131) connected to the electrode 2 on the package 121 side

is connected to an electrode 135 (132) connected to the electrode 3 on the package 122 by a series circuit formed of a resistance R_{12} and an inductance L_{12}. Similarly, an equivalent circuit is formed in which the electrode 134 (131) connected to the electrode 2 on the package 121 side and the electrode 135 (132) connected to the electrode 3 on the package 122 are connected to a capacitance C_{12} through normal connecting wires that can ignore resistance values. More specifically, the equivalent circuit is formed in which the electrode 133 (130) is connected to the electrode 134 (131) by the circuit having $R_{11} + j\omega L_{11}$ and the electrode 134 (131) is connected to the electrode 135 (132) by the circuit having $R_{12} + j\omega L_{12}$ and the circuit having $1/j\omega C_{12}$.

As described above, the attenuation pole impedance of the invention is configured as described with Figs. 6 to 9.

Table 2-1-1 shows the value of attenuation width (MHz) where the attenuation value of the attenuation band on the low frequency side of the pass band is 19.0 (dB) when the attenuation pole impedance Z_{11} is almost constant to the inductance L nearly equal 1 (nH) and the resistance R is a parameter and shows the Q characteristic value of the SAW filter with attenuation poles.

Table 2-1-2 shows the value of attenuation width (MHz) where the attenuation value of the attenuation band on the low frequency side of the pass band is 24.0 (dB) when the attenuation pole impedance Z_{11} is almost constant to the inductance L nearly

equal 0.5 (nH) and the resistance R is a parameter and shows

the Q characteristic value of the SAW filter with attenuation

poles.

Fig. 11 is a diagram for describing the attenuation width

5 of the invention.

In addition, as shown in Fig. 11, the 'attenuation width'

is an interval that the attenuation value of the attenuation

band on the low frequency side of the pass band continues at

a predetermined value or below. 'Predetermined value' is the

10 value that the attenuation value of the attenuation band on

the low frequency side is sufficiently attenuated with respect

to the attenuation value of the pass band in practice. Under

the   present   circumstances,   the   tendency   shows   the

characteristics that can provide sufficient attenuation width,

15 not the characteristics that are greatly attenuated in a narrow

range.

Range of Resistance in the First Embodiment

The attenuation value of the attenuation band on the low

20 frequency side of the pass band and the value of attenuation

width (MHz) are set to be sufficient values at practical levels.

A preferable range of the resistance value to surely clear the

conditions at that time is as follows:

1)   The range of resistance where L is nearly equal 1 (nH)

25 is 0.20 to 1.20 (Ω).

2)   The range of resistance where L is nearly equal 0.5 (nH) is 0.10 to 0.60 (Ω).

Advantage of the First Embodiment

5   As described above, the first embodiment has high attenuation characteristics in the attenuation band on the low frequency side of the pass band.

The traditional response is that the bonding wire is used as the attenuation pole inductance L in order to realize high

10   attenuation characteristics by providing attenuation poles in the attenuation band in the attenuation band on the low frequency side of the pass band, but satisfying characteristics are not obtained.

In the meantime, as compared with the characteristics

15   of the traditional ladder type SAW filter, the first embodiment according to the invention can obtain required characteristics in which the impedance having the real part is used in the two-port circuit for forming the pole frequency and high attenuation characteristics are obtained by the real part of the resistance

20   component along with the impedance such as the bonding wire.

Second Embodiment

Fig. 5 is a schematic diagram illustrating a second embodiment according to the invention.

25   In the second embodiment, a two-port circuit for filtering

1 (180) is configured of a ladder type SAW filter of two-stage π type having the same circuit configuration as that of the first embodiment, and a two-port circuit for impedance 2 (181) is configured of a π type circuit using three impedances. Each

5   of three impedances Z_{21} (241), Z_{22} (242) and Z_{23} (243) is configured of a resistance R and an inductance X.

More specifically, the two-port circuit for filtering 1 (180) configures the π type circuit of one series arm S1 (210) and two shunt arms P1 (220) and P2 (221).

10   The two-port circuit for impedance 2 (181) configures the π type circuit of an attenuation pole impedance Z_{21} (241) having $R_1 + jX_1$, an attenuation pole impedance Z_{22} (242) having $R_2 + jX_2$ and an attenuation pole impedance Z_{23} (243) having $R_3 + jX_3$.

15   The invention is characterized in that high attenuation characteristics can be provided in the pole frequency of the attenuation band on the low frequency side by the real part R and the imaginary part X of the attenuation pole impedances Z_{21}, Z_{22} and Z_{23}.

20   The configuration of each resonator of the second embodiment is the same as the configuration of the first embodiment, shown in Table 3.

Table 3

Configuration	series arm S1	shunt arm P1	shunt arm P2

of resonators	(110)	(120)	(121)
Intersection length (μm)	60	70	70
Logarithm	80	80	80

Z_1 and Z_2 in Equation (8) are given by Equations (6) and (7).

$$Z_2 = ZF_1 + R_{11} + jX_{11} \qquad (6)$$

$$Z_1 = ZF_1 * (ZS_1 + Z_{ss}) / (ZF_1 + ZS_1 + Z_{33}) \qquad (7)$$

where $Z_{ss} = (R_1 + jX_1) * (R_2 + jX_2) / (R_1 + jx_1 + R_2 + jX_2)$.

Accordingly, a coefficient S of operating transmission is evaluated by Equation (7) from Equation (6).

$$S = \frac{Z_1 + Z_2 + Z_1 Z_2 + 1}{Z_2 - Z_1} \qquad (8)$$

The attenuation characteristic of the second embodiment can be determined by putting Equations (6) and (7) in Equation (8). More specifically, the difference from the first embodiment is in that Equations (6) and (7) are put in Equation (8) for determination because the π type circuit configuration is used in the two-port circuit 2. Accordingly, the pole frequency is a frequency that the denominator of Equation (8) is zero, and the attenuation characteristic becomes high attenuation characteristics, being different from traditional ones.

Hereinafter, the frequency band of the cdmaOne filter will be exemplified to describe the usability of the invention with reference to Table 4. Table 4 shows resonators, the series

arm and the shunt arms configuring the circuit shown in Fig. 5.

The upper part of Table 4-2-1 shows the value of attenuation width (MHz) where the attenuation value of the low frequency side of the attenuation band of the pass band is 15.5 (dB) when the attenuation pole impedances Z_{21}, Z_{22} and Z_{23} are almost constant to the inductances L1 to L3 nearly equal 0.5 (nH) and the resistance R is a parameter, and shows the Q characteristic value of the SAW filter with attenuation poles.

The lower part of Table 4-2-1 shows the value of attenuation width (MHz) where the attenuation value of the attenuation band on the low frequency side of the pass band is 22.0 (dB) when the attenuation pole impedances Z_{21}, Z_{22} and Z_{23} are almost constant to the inductances L1 and L3 nearly equal 0.5 (nH) and to the inductance L2 nearly equal 0.2 (nH) and the resistance R is a parameter, and shows the Q characteristic value of the SAW filter with attenuation poles.

The upper part of Table 4-2-2 shows the value of attenuation width (MHz) where the attenuation value of the attenuation band on the low frequency side of the pass band is 15.5 (dB) when the attenuation pole impedances Z_{21}, Z_{22} and Z_{23} are almost constant to the inductances L1 to L3 nearly equal 1.0 (nH) and the resistance R is a parameter, and shows the Q characteristic value of the SAW filter with attenuation poles.

The middle part of Table 4-2-2 shows the value of

attenuation width (MHz) where the attenuation value of the attenuation band on the low frequency side of the pass band is 24.1 (dB) when the attenuation pole impedances Z_{21}, Z_{22} and Z_{23} are almost constant to the inductances L1 and L3 nearly equal

5   1.0 (nH) and to the inductance L2 nearly equal 0.2 (nH) and the resistance R is a parameter, and shows the Q characteristic value of the SAW filter with attenuation poles.

The lower part of Table 4-2-2 shows the value of attenuation width (MHz) where the attenuation value of the

10   attenuation band on the low frequency side of the pass band is 17.2 (dB) when the attenuation pole impedances Z_{21}, Z_{22} and Z_{23} are almost constant to the inductances L1 and L3 nearly equal 1.0 (nH) and to the inductance L2 nearly equal 0.5 (nH) and the resistance R is a parameter, and shows the Q characteristic

15   value of the SAW filter with attenuation poles.

Table 4

2-1. Attenuation pole inductance L is 0.5 (nH)

15.5 dB Width	9.8	10.8	12.3	13.3	13.2	13.5	12	11
R (OHM)	2.00	1.00	0.60	0.40	0.30	0.20	0.10	0.01
L1, L3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
L2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Q	1	2.5	5	7.5	10	15	20	1000

15.5 dB Width	7.5	9.2	10	10.7	10.7	11.3	10	8
R (OHM)	2.00	1.00	0.60	0.40	0.30	0.20	0.10	0.01
L1, L3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
L2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Q	1	2.5	5	7.5	10	15	20	1000

2-2. Attenuation pole inductance L is 1.0 (nH)

15.5 dB Width	18.3	20.3	23.3	26	26.4	26.8	26.7	21.5
R (OHM)	4.00	2.00	1.20	0.80	0.60	0.40	0.20	0.01
L1, L3	1	1	1	1	1	1	1	1
L2	1	1	1	1	1	1	1	1
Q	1	2.5	5	7.5	10	15	20	1000

15.5 dB Width	4.4	6.6	8.3	8.7	8.8	8.9	8.7	6.5
R (OHM)	4.00	2.00	1.20	0.80	0.60	0.40	0.20	0.01
L1, L3	1	1	1	1	1	1	1	1
L2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Q	1	2.5	5	7.5	10	15	20	1000

15.5 dB Width	12.3	14.3	17.2	19.1	19.5	19.8	19.7	16
R (OHM)	4.00	2.00	1.20	0.80	0.60	0.40	0.20	0.01
L1, L3	1	1	1	1	1	1	1	1
L2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Q	1	2.5	5	7.5	10	15	20	1000

Range of Resistance in the Second Embodiment

The attenuation value of the attenuation band on the low frequency side of the pass band and the value of attenuation width (MHz) are set to sufficient values at practical levels. A preferable range of the resistance value to surely clear the conditions at that time is as follows:

1) The range of resistance is 0.20 to 1.20 (Ω) when L is nearly equal 1 (nH).

2) The range of resistance is 0.10 to 0.60 (Ω) when L is nearly equal 0.5 (nH).

Traditionally, as a scheme to obtain high attenuation characteristics, the response is that the bonding wire is used

as the attenuation pole inductance L to form attenuation poles in the attenuation band as described in the related document.

The second embodiment according to the invention can obtain high attenuation characteristics in which the resistance component is used in addition to the bonding wire and thus the attenuation pole frequency and the attenuation characteristic can be varied without changing the pass band characteristics. Particularly, the improvement in the attenuation characteristic is significant, allowing a bandwidth of 20 (dB) to be a broad band.

Relationship between the Attenuation Width and Resistance of the SAW Filter with Attenuation Poles

Fig. 10 is a graph summarizing the characteristics of Tables 2 and 4 of the invention.

Characteristic curve (1) depicts Table 2-1-1.

Characteristic curve (2) depicts Table 2-1-2.

Characteristic curve (3) depicts the upper part of Table 4-2-1.

Characteristic curve (4) depicts the lower part of Table 4-2-2.

Characteristic curve (5) depicts the upper part of Table 4-2-2.

Characteristic curve (6) depicts the middle part of Table 4-2-2.

Characteristic curve (7) depicts the lower part of Table 4-2-2.

Points a, a', b, b', c, c', d, d', e, e', f, f', g and g' of each of the characteristic curves mean 'a predetermined value' expressing the interval where the attenuation value of the attenuation band on the low frequency side of the pass band continues at a predetermined value or below, meaning an effective range including the preferable ranges described above.

The conditions for good items are that the range of resistance is 0.1 to 0.6 (Ω) when the attenuation pole inductance L is nearly equal 0.5 (nH).

The conditions for good items are that the range of resistance is 0.1 to 1.2 (Ω) when the attenuation pole inductance L is nearly equal 1.0 (nH).

The attenuation pole impedance tends to broaden the range of resistance as the value of inductance L is increased.

The relationship between the inductance and resistance can be selected based on these characteristic curves.

As described above, the invention has high attenuation characteristics in the attenuation band on the low frequency side of the pass band.

The invention can obtain required characteristics in which the impedance having the real part is used in the two-port circuit for forming the pole frequency and high attenuation characteristics are provided by the real part of the resistance

component along with impedance such as the bonding wire, as compared with the characteristics of the traditional ladder type SAW filter.